

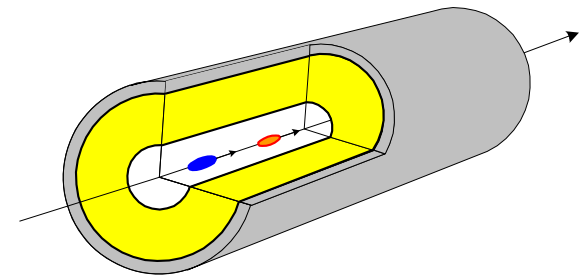
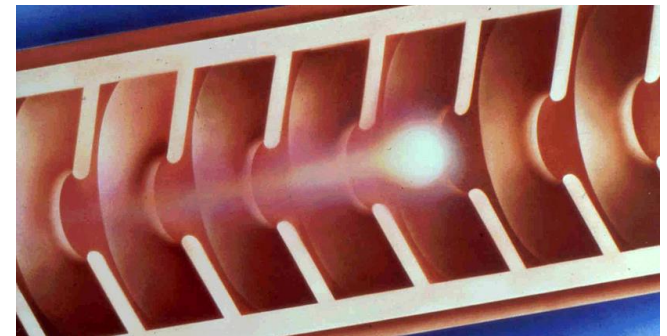
AE52: Beam Manipulation by Self-Wakefield at the ATF

Sergey Antipov

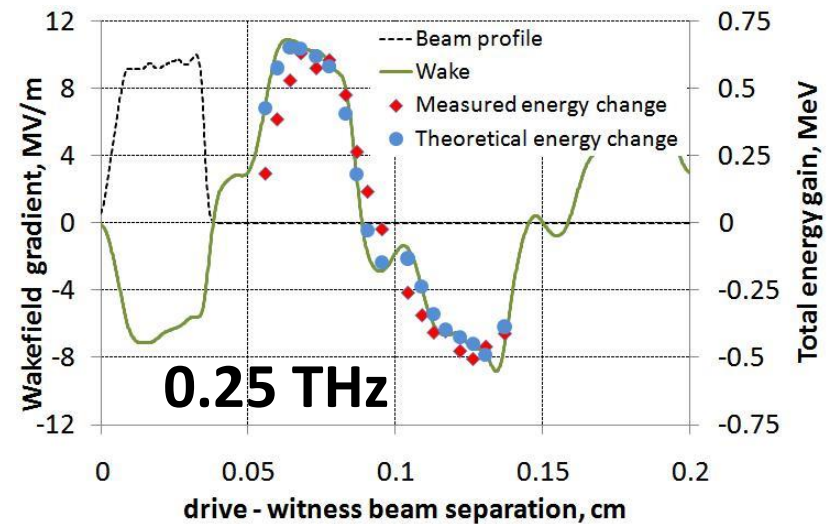
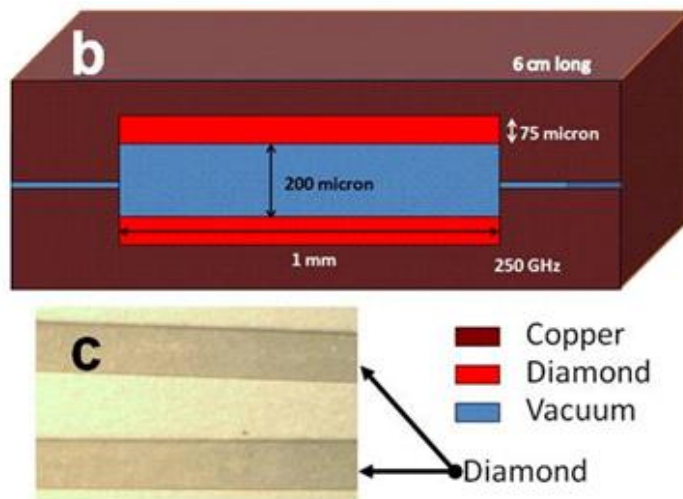
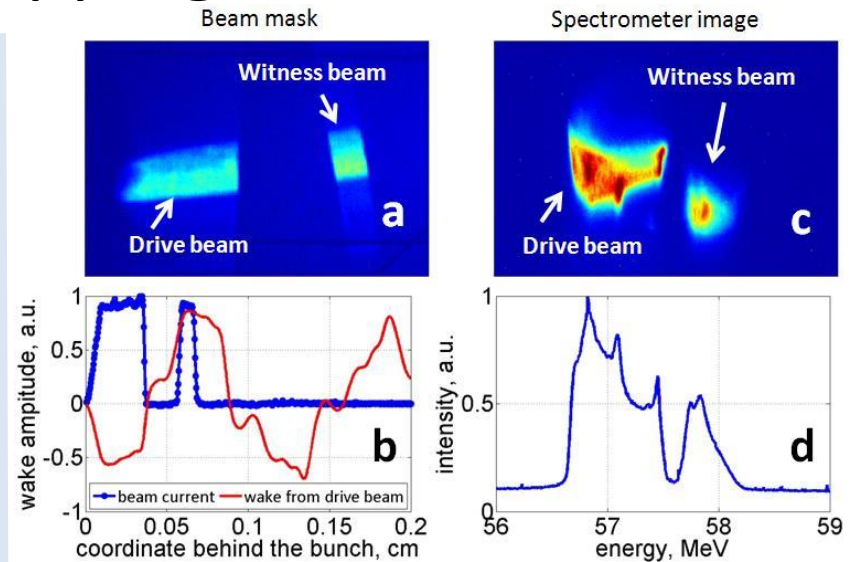
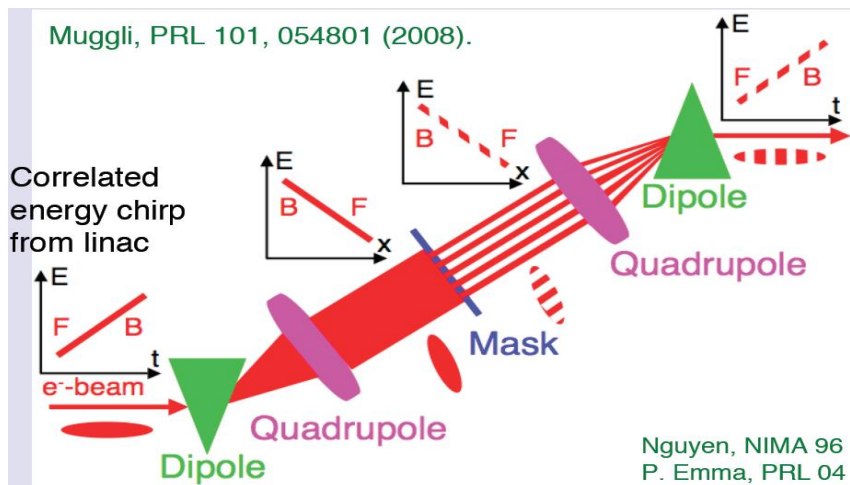
Euclid Techlabs LLC

Argonne National Laboratory

- **AE52 - Beam manipulation by self-wakefield**
- **AF57 - THz generation in a corrugated metal structure (with Karl Bane)**
- Various structures
 - dielectric loaded, corrugated, single mode, multimode
- Study of wakefield (/THz)
- Study of self-wakefield
 - Dechirper, energy modulation, transformer ratio



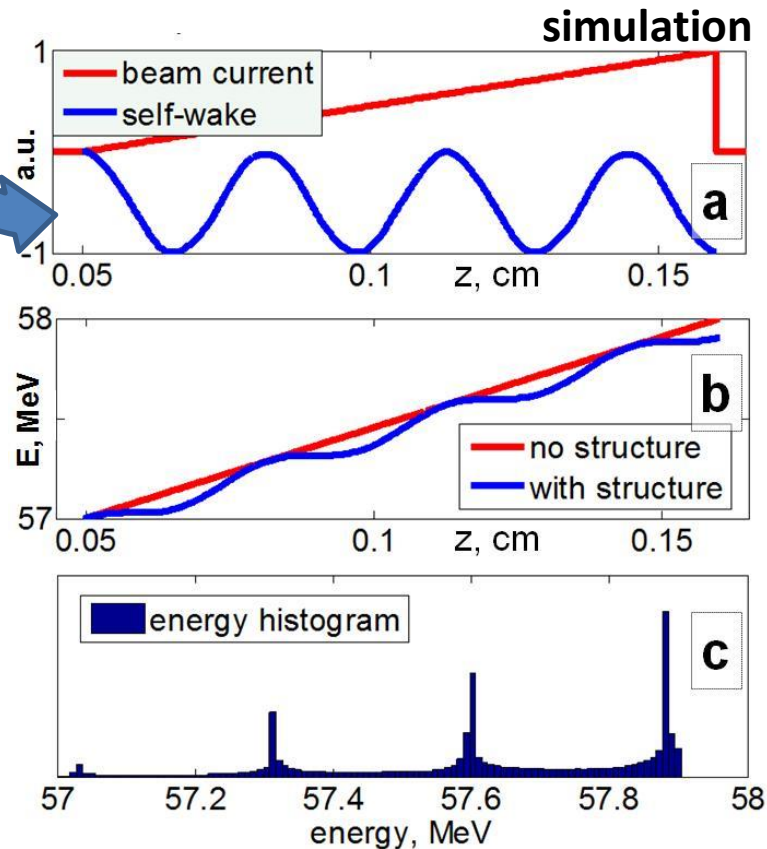
Wakefield Mapping at ATF



S. Antipov, C. Jing, A. Kanareykin, J. E. Butler, V. Yakimenko, M. Fedurin, K. Kusche, and W. Gai, *Appl. Phys. Lett.* 100, 132910 (2012)

Observation of energy modulation at ATF

Periodic self-deceleration!

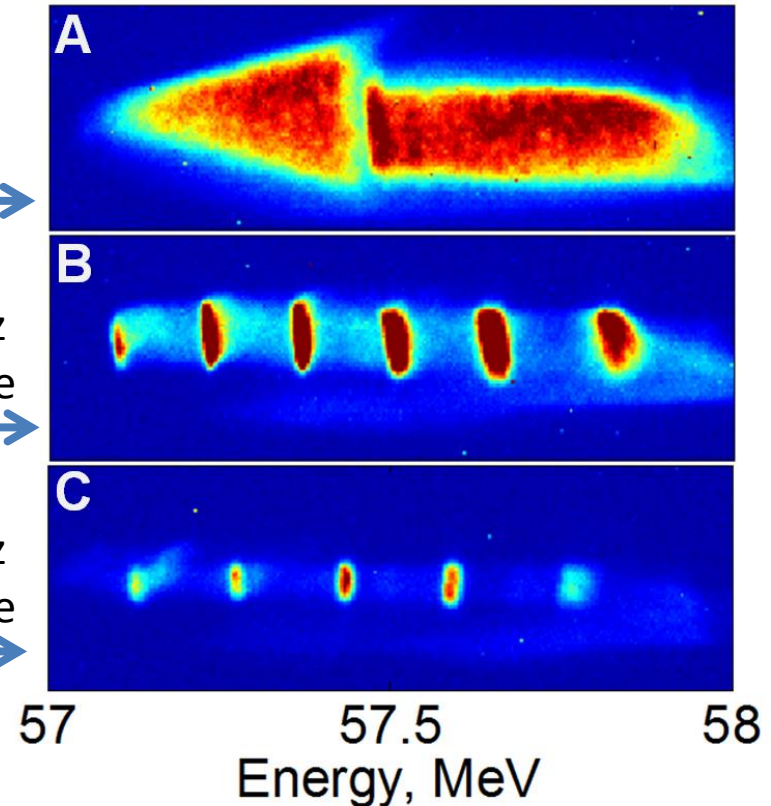


Original chirped beam

0.95 THz structure

0.76 THz structure

Measurement: spectrometer

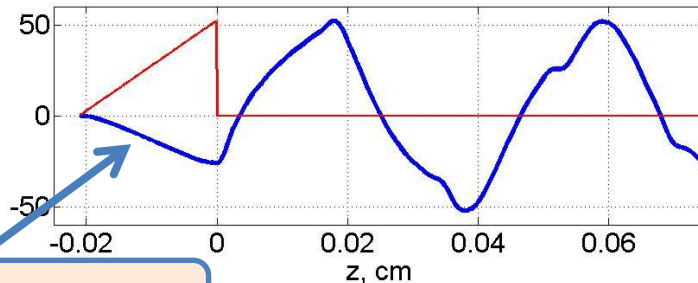


S. Antipov, C. Jing, M. Fedurin, W. Gai, A. Kanareykin, K. Kusche, P. Schoessow, V. Yakimenko, A. Zholents, Phys. Rev. Lett. 108, 144801 (2012)

Energy Chirp Correction Experiment at ATF

Triangular-shaped (current) beam with energy chirp

wake from $\Delta_z = 210\mu$, 300 μ ID / 400 μ OD quartz tube



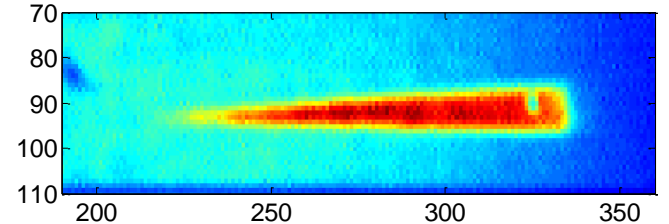
Self-deceleration!



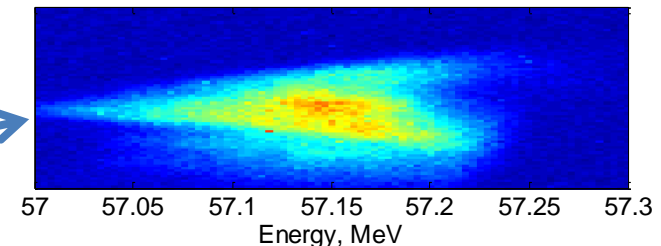
Chirp corrector – passive wakefield tube: dielectric loaded waveguide

Spectrometer image of the original beam

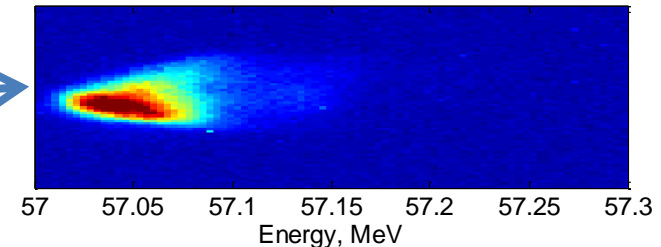
beam image after the mask, triangle length is 247 micron



spectrometer image of unperturbed beam

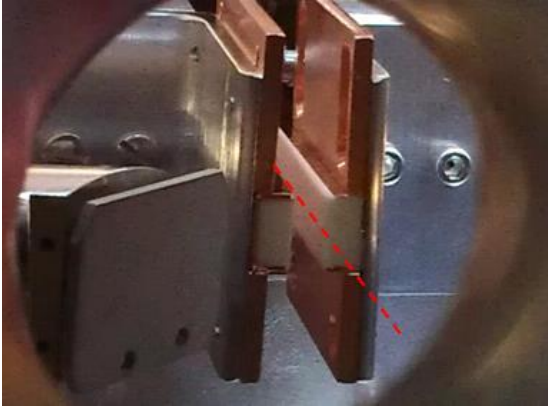


spectrometer image of a beam that passed through the structure

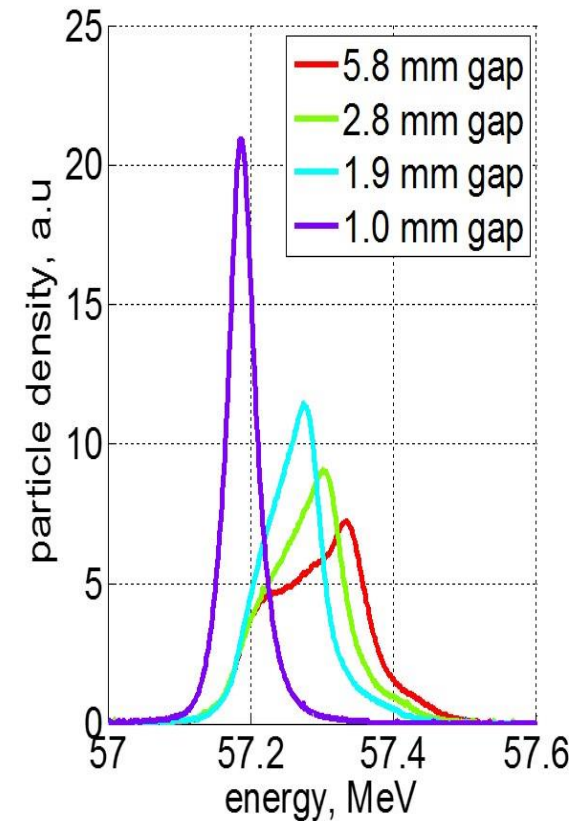
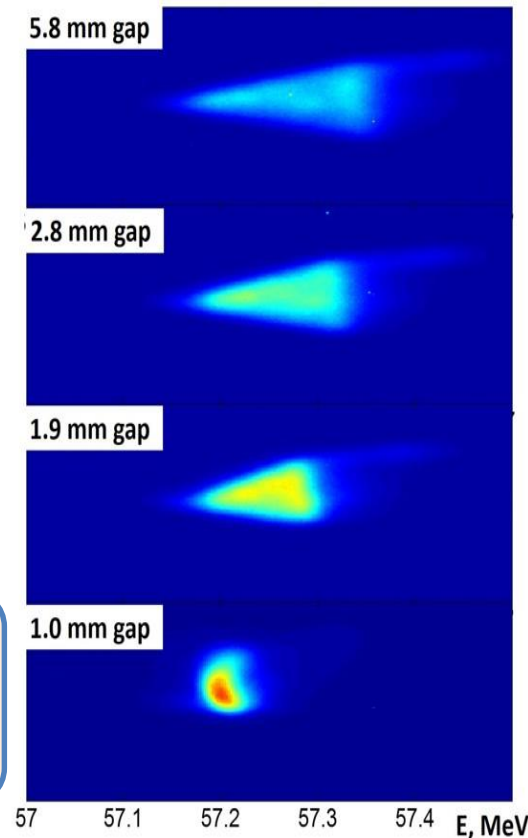


S. Antipov, C. Jing, M. Fedurin, W. Gai, A. Kanareykin, K. Kusche, P. Schoessow, V. Yakimenko, and A. Zholents, Phys. Rev. Lett. 108, 144801 (2012)

Tunable Energy Chirp Correction Experiment at ATF



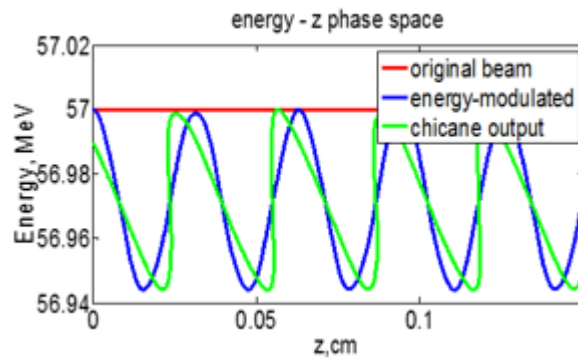
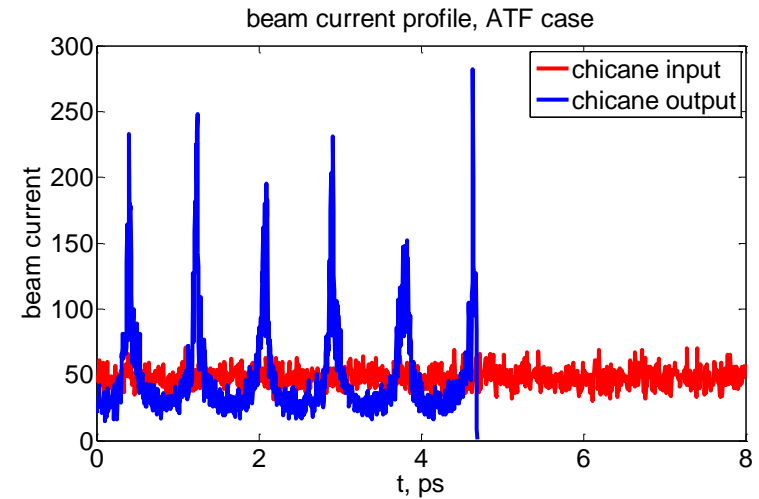
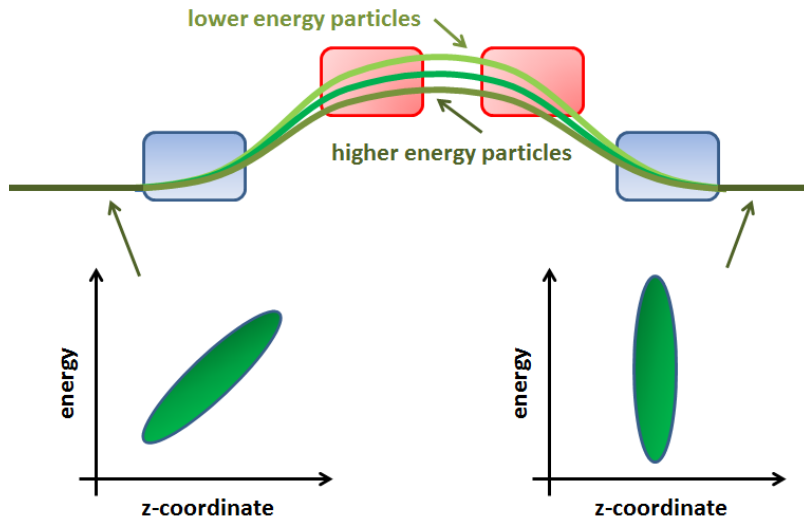
dechirper: multimode rectangular dielectric loaded waveguide with tunable beam gap



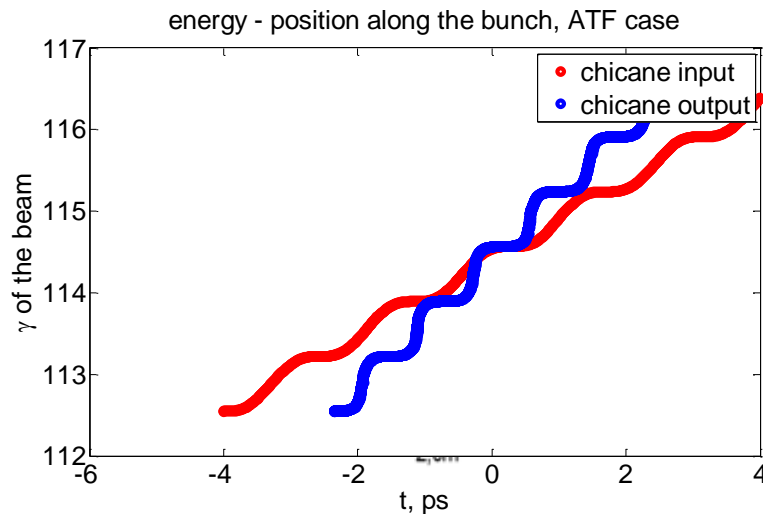
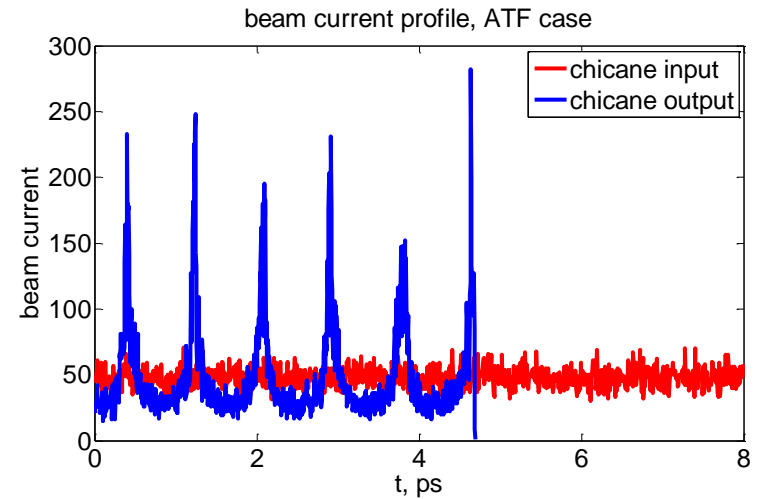
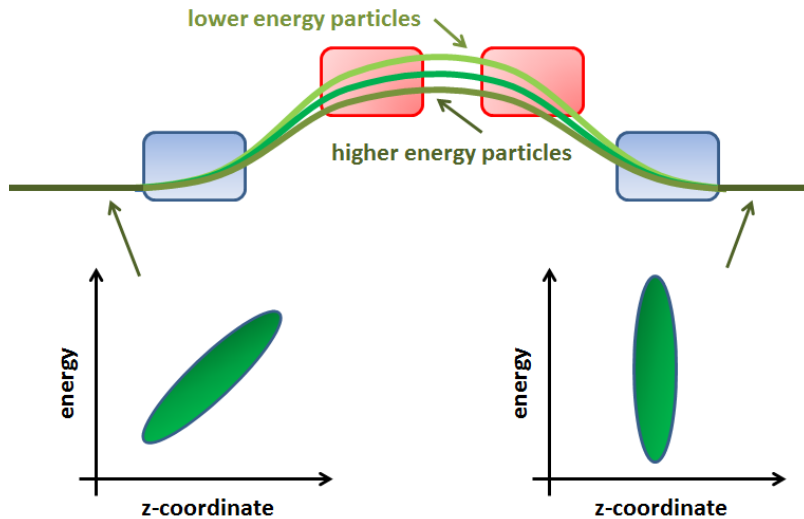
S. Antipov, S. Baturin, C. Jing, M. Fedurin, A. Kanareykin, C. Swinson, P. Schoessow, W. Gai, and A. Zholents, Phys. Rev. Lett. 112, 114801 (2014)

Triangular-shaped (current) beam with energy chirp
Correlated energy spread was removed by closing the dechirper gap

Chicane: energy \rightarrow density modulation



Chicane: energy \rightarrow density modulation

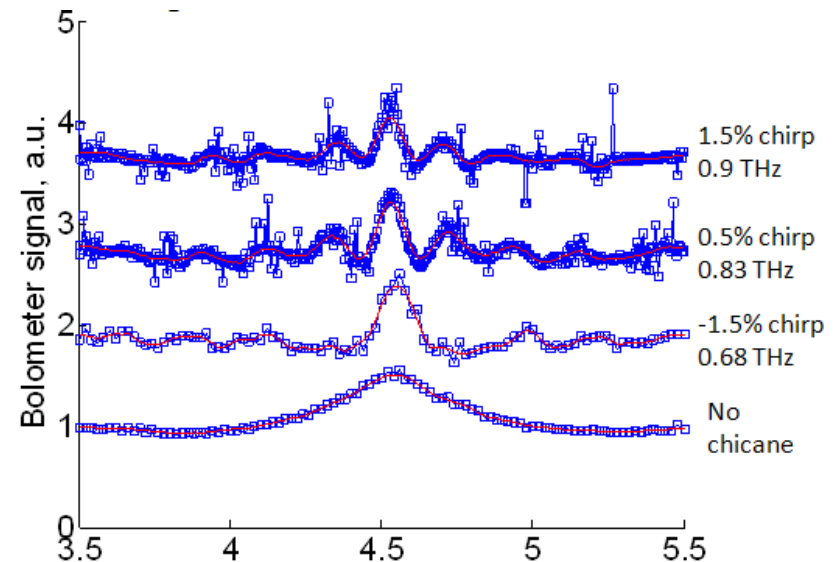
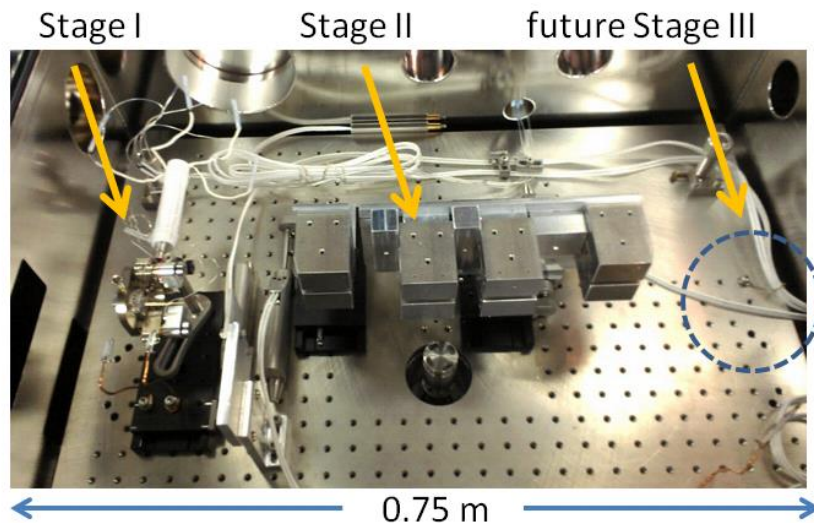


- Chirp = Energy – z correlation
- Chirp is convenient for experiment
- Chirp allows to increase the bunch train frequency for a given wakefield modulation structure

Sub-picosecond bunch train production at ATF

PM chicane is used to convert energy modulation into density modulation

CTR interferometry shows that THz periodicity can be tuned by energy chirp



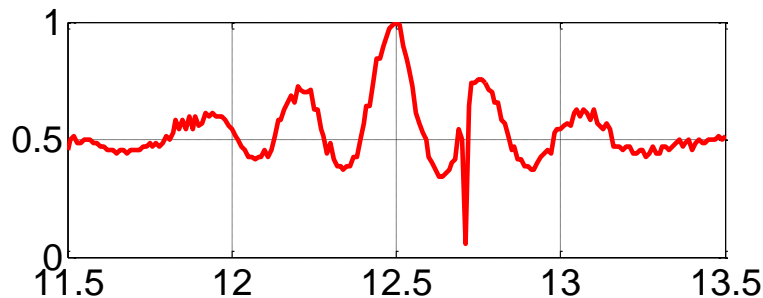
We proposed a high power terahertz radiation source based on this scheme (electron beam wakefields). A third stage, yet another dielectric tube will be installed after chicane to coherently extract THz power from the bunch train

S. Antipov, M. Babzien, C. Jing, M. Fedurin, W. Gai, A. Kanareykin, K. Kusche, V. Yakimenko, A. Zholents, prepared for Phys. Rev. Lett.

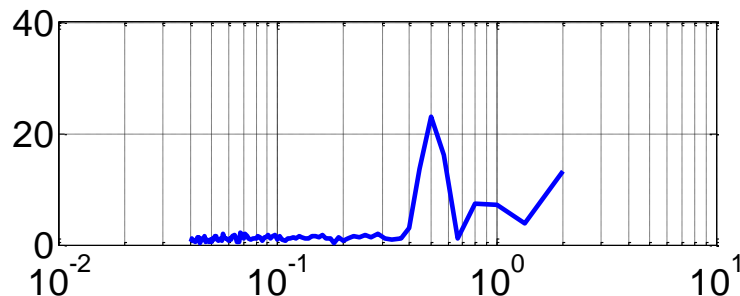
THz signal generation and characterization

- Bunch train characterization

Interferometer + LHe bolometer
Autocorrelation function

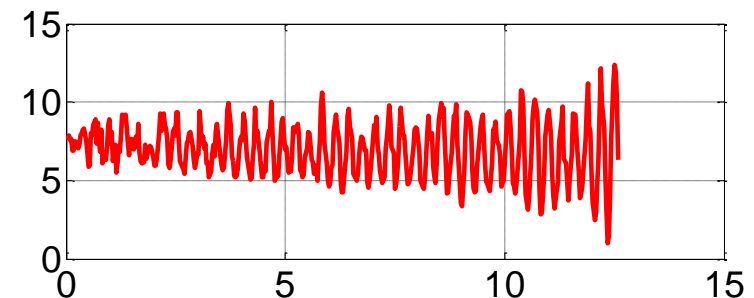


Coherent transition radiation (wide band)

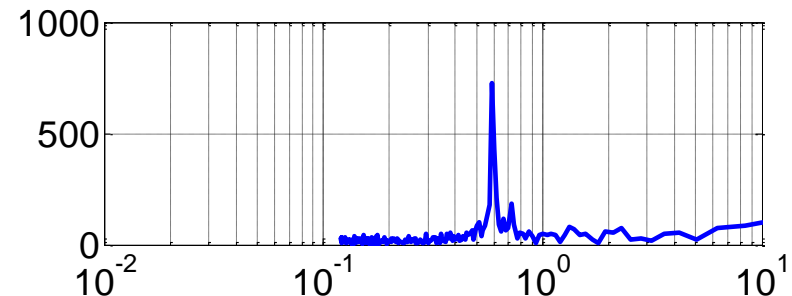


- Cherenkov radiation

Narrow band THz radiation generation:
0.4 – 1.2 THz, $\sim 1\%$ bandwidth

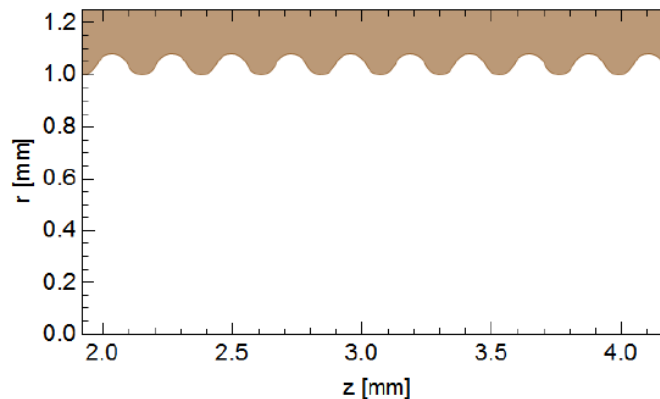


Energy per pulse few 10uJ



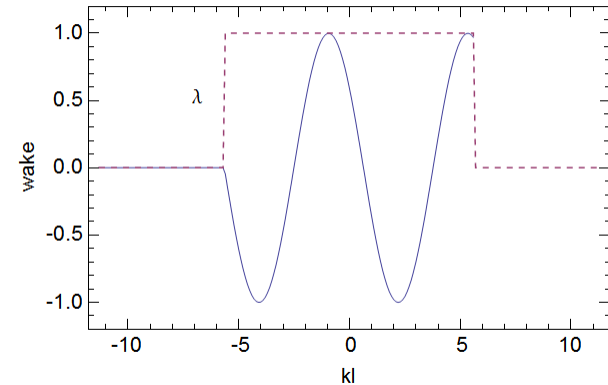
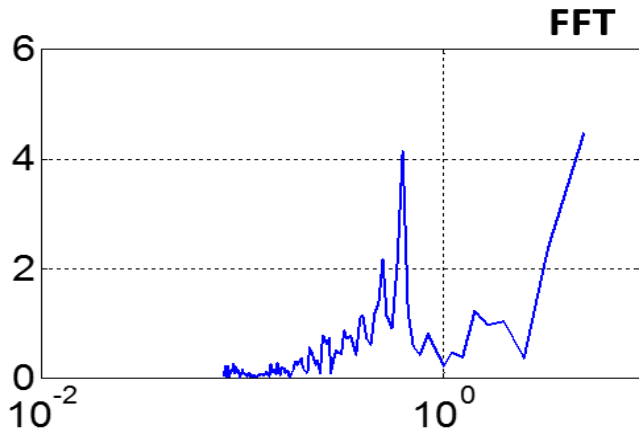
AF57: THz generation in a corrugated metal structure

- Structure: ID=2mm, L=5 cm, period=230 μ m, corrugations 60 μ m deep
- $f = 420$ GHz, pulse length ~ 6 mm
- Bandwidth $\sim 12\%$
- ATF beam: 50pC, $\sigma_z = 60\mu\text{m}$ (rms) $\rightarrow 1\mu\text{J}$ per pulse
- Wall loss $\sim 0.22\mu\text{J}$

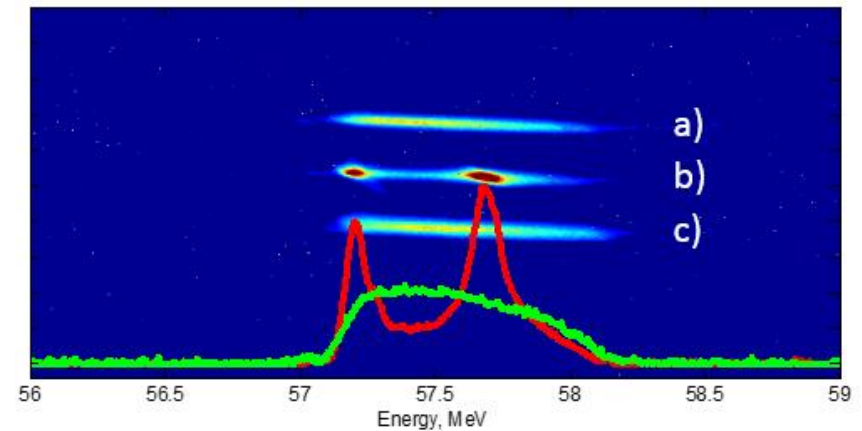
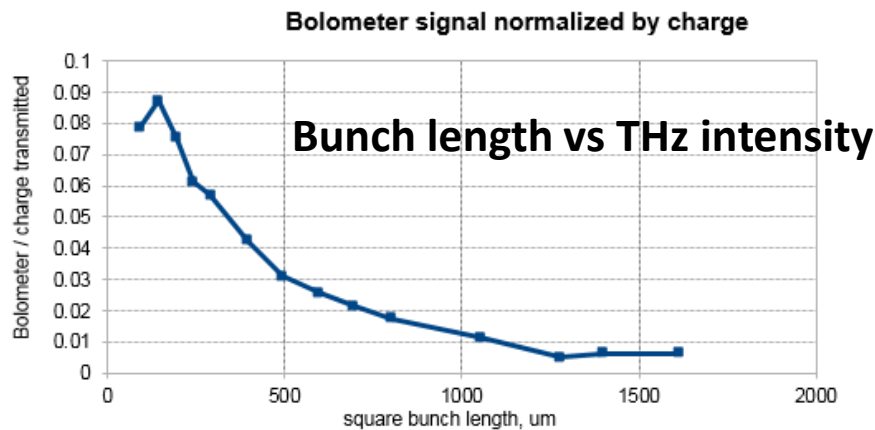


THz generation in a T-pipe. Results

Frequency measured: 459 ± 32 GHz

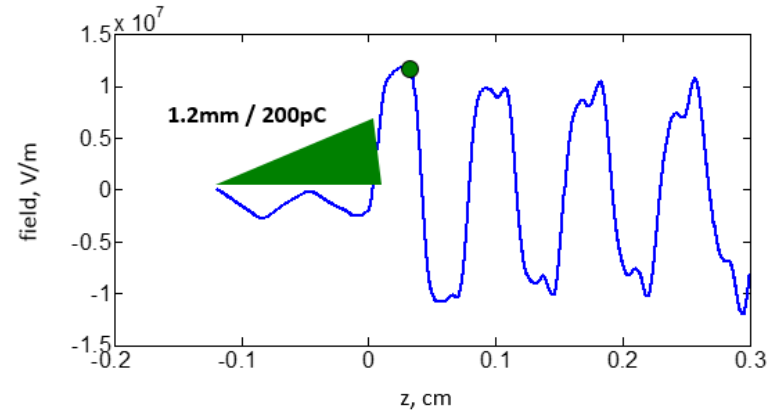
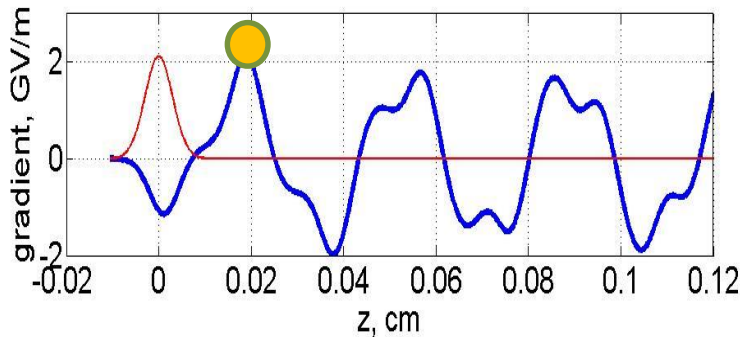


Spectrometer measurement
energy modulation



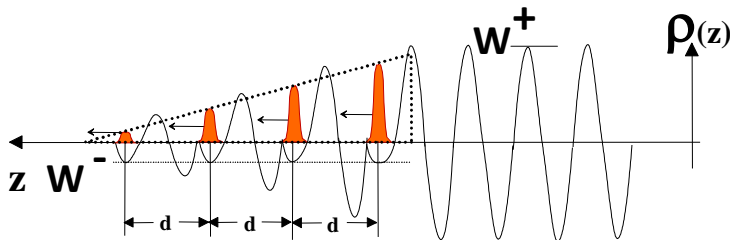
Collinear Acceleration, Transformer Ratio

wake from $\sigma_z = 30\mu$, 1nC beam, 150 μ ID / 250 μ OD quartz tube

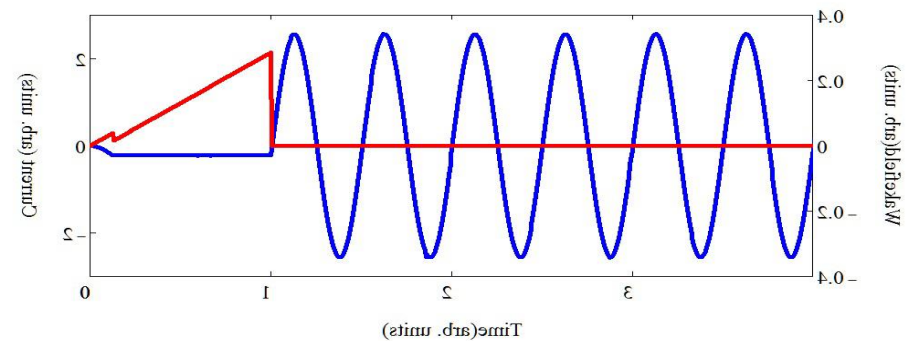


Transformer Ratio:

$$TR = \frac{E_{\max \text{ gain}}}{E_{\max \text{ loss}}}$$



Using this method, $TR = 3.4$ was demonstrated experimentally at AWA, ANL

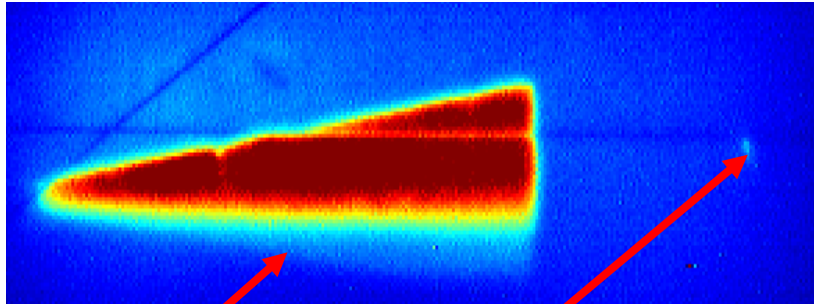


C. Jing et. al. PRL, 98, 144801, April (2007)

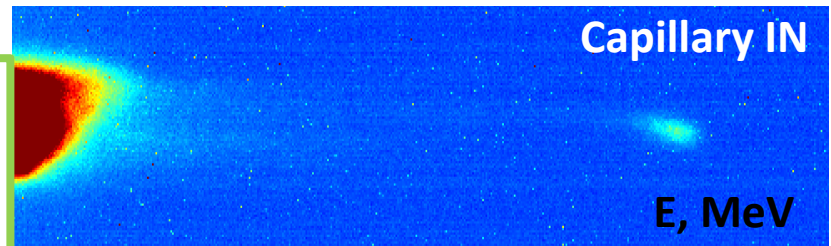
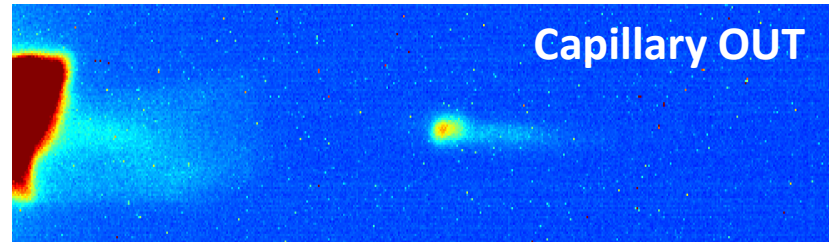
C.Jing et. al. PR ST-AB, 14, 021302, Feb. (2011)

Transformer ratio measurement at ATF

Beam profile after the mask in a dogleg

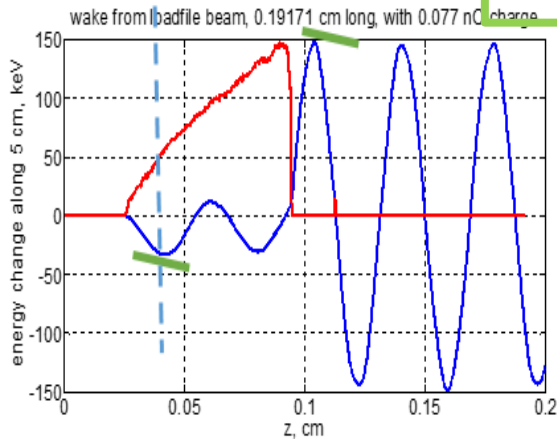


- Small witness beam: spectrometer



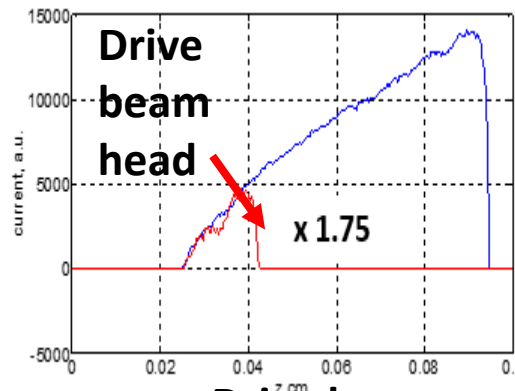
Drive (77 pC) and
witness (3.5 pC)

Theoretical: 4.5
Measured: 3.5



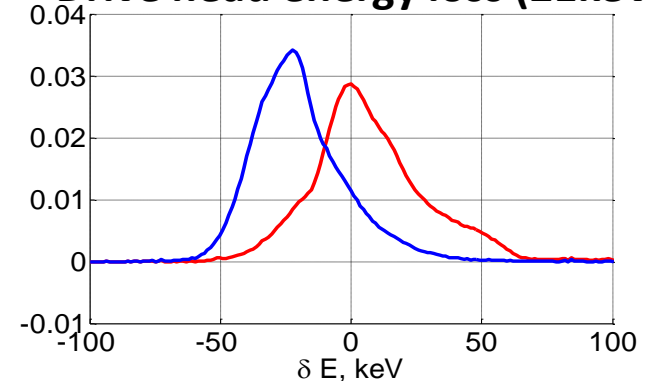
S. Antipov, prepared for publication (2014)

***preliminary data**



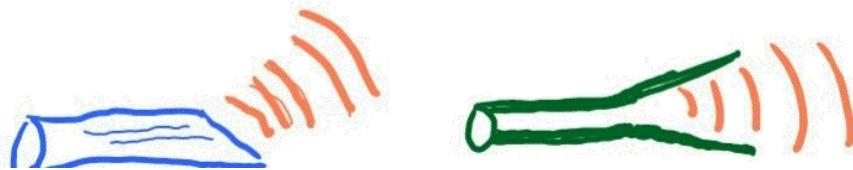
Drive beam current

Drive head energy loss (21keV)



Request for extension (AE52) / future plans

- THz extraction system + THz energy/power measurement



- Full 3-stage THz source demonstration. THz generation by a bunch train



- Further transformer ratio studies with new bunch shapes



- Beam stability studies in DWFA. Practical design for wakefield acceleration (focusing optics around the capillary)